CHARACTERIZATION OF FLY ASH FOR THEIR EFFECTIVE MANAGEMENT AND UTILIZATION

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

MINING ENGINEERING

By

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NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA, ORISSA - 769008

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CERTIFICATE

This is to certify that the thesis entitled **"characterisation of fly ash for their effective management and utilization"** submitted by **Sri Rakesh Kumar Behera** in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Mining Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

Prof. H.K.NAIK

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Date: **RAKESH KUMAR BEHERA**

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ABSTRACT

Large amount of fly ash discharged from coal-fired power stations is a major problem. Amount of fly ash available can be recycled, mainly by adding fly ash to cement. However, the addition of fly ash to cement is limited because the production rate of cement is leveled off, and also the concentration of fly ash in cement is limited.

Researchers have studied the aspect of particle size distribution, permeability, slurry flow characteristics, settling characteristics, slump characteristics and so on for mill tailings. Fly ash in terms of particle size and mineralogical composition is similar to mill tailings. There is however not much literature available on direct placement of fly ash as a fill material. Investigations on the fly ash have been largely confined to determining physico-chemical properties, strength properties (as cement substitute or with binders). The present study therefore makes use of literature available in terms of fly ash, to design and conduct different experiments on settling rate and hydraulic transportation aspects of fly ash.

Different experiments were conducted to find the pH at different levels of lime, cement and gypsum. These were done to further utilize the cementing property of fly ash and its use for support and fill the mine voids as well as construction of cement of different strength levels. It was observed that the strength level increase with the increase in the percentage of lime and it was observed to be maximum at 4% of lime and 8 % cement and 4% gypsum. Thus as pH is directly related to strength so it indicated that the strength characteristics was further enhanced using the aforesaid composition. The SEM of the samples were done to study the characteristics of individual elements as the element having spherical shapes showed maximum pozzolanic character.

CHAPTER-1

INTRODUCTION

OBJECTIVES

1.1 INTRODUCTION

The combustion of pulverized coal at high temperatures and pressures in power stations produces different types of ash.

The 'fine' ash fraction is carried upwards with the flue gases and captured before reaching the atmosphere by highly efficient electro static precipitators. This material is known as Pulverized Fuel Ash (PFA) or 'fly ash'. It is composed mainly of extremely fine, glassy spheres and looks similar to cement. The 'coarse' ash fraction falls into the grates below the boilers, where it is mixed with water and pumped to lagoons. This material, known as Furnace Bottom Ash (FBA) has a gritty, sand-like texture.

Fly ash closely resembles volcanic ashes used in production of the earliest known hydraulic cements about 2,300 years ago. Those cements were made near the small Italian town of Pozzuoli - which later gave its name to the term "pozzolan." A pozzolan is a siliceous or siliceous / aluminous material that, when mixed with lime and water, forms a cementitious compound. Fly ash is the best known, and one of the most commonly used, pozzolans in the world.

Instead of volcanoes, today's fly ash comes primarily from coal-fired electricity generating power plants. These power plants grind coal to powder fineness before it is burned. Fly ash - the mineral residue produced by burning coal - is captured from the power plant's exhaust gases and collected for use.

Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron.

The difference between fly ash and portland cement becomes apparent under a microscope. Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures. That capability is one of the properties making fly ash a desirable admixture for concrete.

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, whereas bottom ash is removed from the bottom of the furnace. In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Fly ash is commonly used to supplement Portland cement in concrete production, where it can bring both technological and economic benefits, and is increasingly finding use in the synthesis of geopolymers and zeolites.

1.2 OBJECTIVES

The object of this study is “characterization of fly ash for their effective management and utilization”. This requires following specific objectives:

1.2.1 SPECIFIC OBJECTIVES

- Study engineering properties
- Settling characteristics of the fly ash samples collected.
- Particle size analysis of fly ash
- BET- Surface area of fly ash

CHAPTER-2

LITERATURE REVIEW

GENERATION

CLASSIFICATION

FEATURES

NATURE AND COMPOSITION

UTILIZATION

COLLECTION

TRANSPORTATION

CHARECTERISTICS OF FLY ASH SLURRY

FLY ASH MANAGEMENT

2.1 GENERATION OF FLY ASH

Fly ash is produced by coal-fired electric and steam generating plants. Typically, coal is pulverized and blown with air into the boiler's combustion chamber where it immediately ignites, generating heat and producing a molten mineral residue. Boiler tubes extract heat from the boiler, cooling the flue gas and causing the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric baghouses.

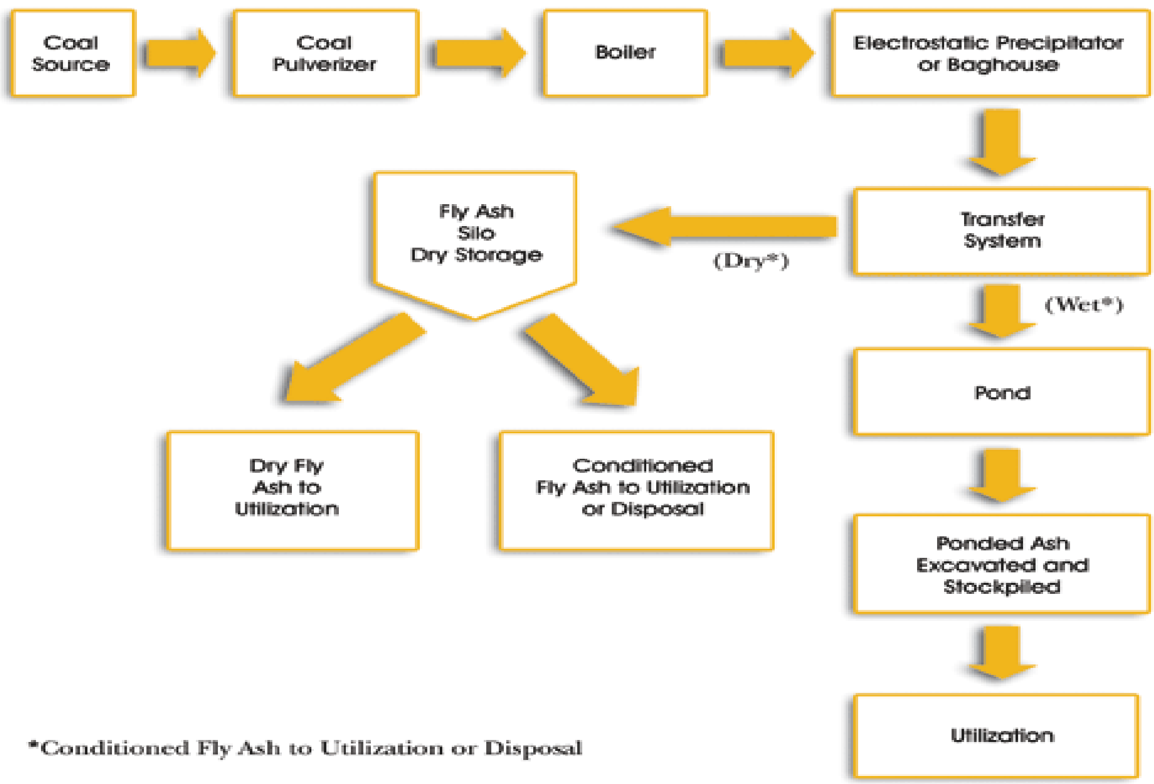


Figure: 2.1 Method of fly ash transfer can be dry, wet or both

Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, and is one of two types of ash that jointly are known as **coal ash**; the other, bottom ash, is removed from the bottom of coal furnaces. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic ingredients in many coal bearing rock strata.

Toxic constituents depend upon the specific coal bed makeup, but may include one or more of the following elements or substances in quantities from trace amounts to several percent: arsenic, beryllium, boron, cadmium, chromium, chromium VI, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds.

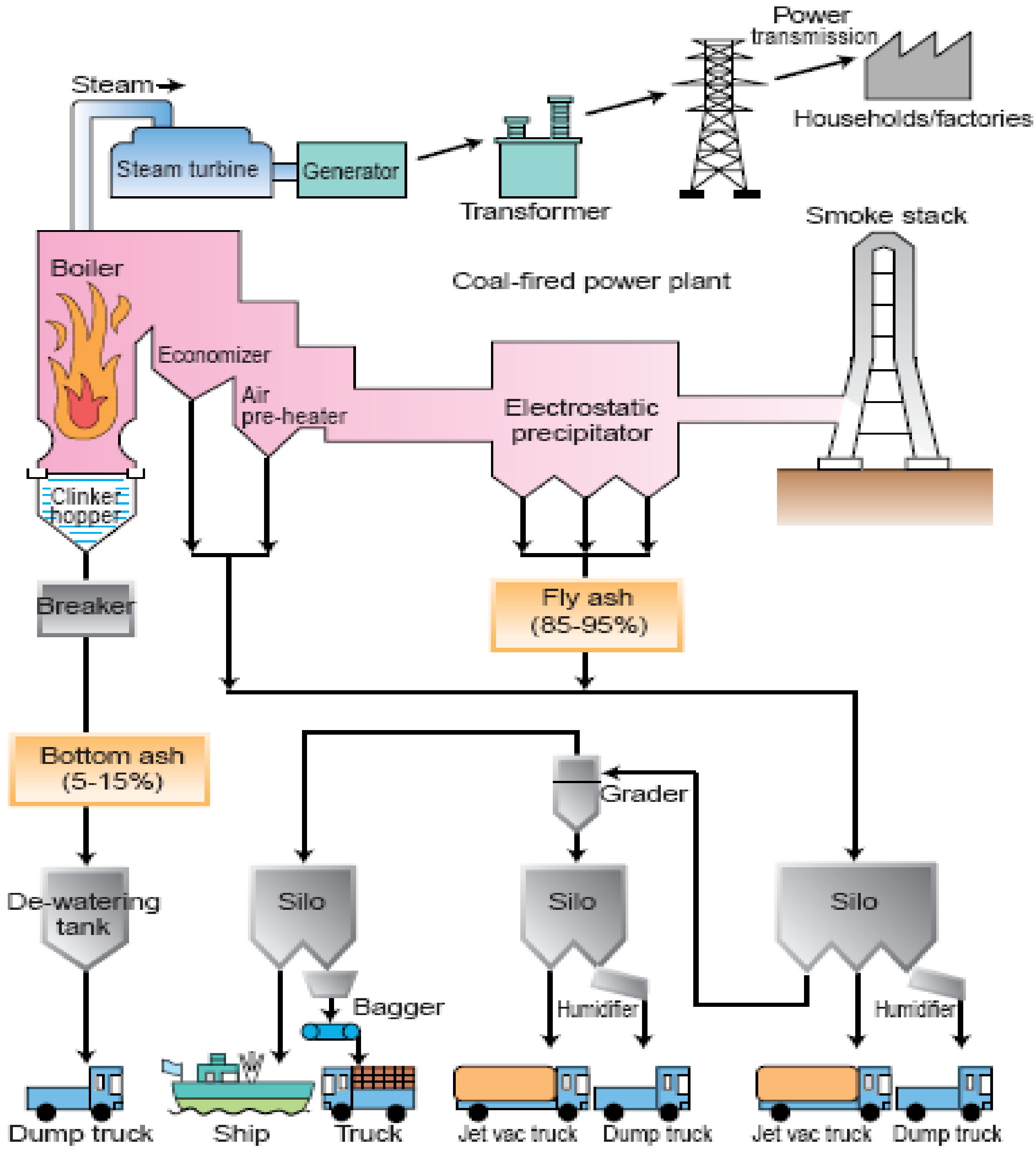


Figure: 2.2 Coal ash generations from a pulverized coal-fired boiler

(Source: Japan Fly Ash Association)

In the past, fly ash was generally released into the atmosphere, but pollution control equipment mandated in recent decades now requires that it be captured prior to release. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43 percent is recycled, often used to supplement Portland cement in concrete production.

In India the annual production of flyash is nearly 45 million tones per year. This is likely to increase to 70 million tons per year by 2010. At present most of the flyash is being dumped. The disposal of the flyash is a serious hazard to the environment that consumes millions of rupees towards the cost of its disposal. About 14000 Hect. Of precious land have already been used for dumping it and another thousand of Hect. Would be required in future.

In India coal/lignite based thermal power stations account for more than 55% of the electricity installed capacity and 65% of electricity generation. The ash content of the coal used at the thermal stations ranges from 30-40%, with the average ash content around 35%.Since low ash, high grade coal is reserved for metallurgical industries; the thermal power plants have to utilize high ash, low grade coal.

The thermal power plant ash generation has increased from about 40 million tones during 1993-1994 to 120million tonnes during 2005-06 and is expected to be in the range of 175 million tonnes per year by 2012, on account of the proposal to double the power generation. Coupled with this, the deteriorating quality (increasing ash quantity) of coal is expected to aggravate the situation.

Table: 2.1 Fly ash generation and utilization in different countries

SL NO	Country	Annual ash production, MT	Ash utilization %
1	India	112	38
2	China	100	45
3	USA	75	65
4	Germany	40	85
5	UK	15	50
6	Australia	10	85
7	Canada	6	75
8	France	3	85
9	Denmark	2	100
10	Italy	2	100
11	Netherlands	2	100

As per estimates, the annual fly ash generation in the country in 2007-08 (data of 2008-09 under compilation, expected to be 150 million tonnes) was about 125 million tonnes; fly ash recycled is about 30 per cent, i.e about 40 million tonnes. Out of this the cement industry consumes around 28-30 million tonnes which is above 70 per cent of the recycled ash. Hence, there is still a huge surplus of 85 million tonnes which is being disposed off as slurry in the ponds.

Another approximately 78,000 mw of new power generation capacity is expected to come up in the country within three-four years. Out of this major portion of around 60 per cent would come in form of thermal power. Estimated generation of fly ash till 2012 would be 175 million tonnes, which again would pose a serious problem of disposal. The major consumer of fly ash is the cement industry only, while some small quantities are used for making flyash bricks, landfill etc.

As per the table, the utilization of fly ash in the cement industry in manufacturing PPC cement is increasing on yearly basis. Further motivation and freight equalization to cement industry can result into 100 per cent fly ash disposal in a most eco-friendly manner.

2.2 CLASSIFICATION

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 100 µm. They consist mostly of silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous; aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3). Fly ashes are generally highly heterogeneous, consisting of a mixture of glassy particles with various identifiable crystalline phases such as quartz, mullite, and various iron oxides.

Fly ash also contains environmental toxins in significant amounts, including arsenic (43.4 ppm); barium (806 ppm); beryllium (5 ppm); boron (311 ppm); cadmium (3.4 ppm); chromium (136 ppm); chromium VI (90 ppm); cobalt (35.9 ppm); copper (112 ppm); fluorine (29 ppm); lead (56 ppm); manganese (250 ppm); nickel (77.6 ppm); selenium (7.7 ppm); strontium (775 ppm); thallium (9 ppm); vanadium (252 ppm); and zinc (178 ppm).

Two classes of fly ash are defined by ASTM C618: Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

Not all fly ashes meet ASTM C618 requirements, although depending on the application, this may not be necessary. Ash used as a cement replacement must meet strict construction standards, but no standard environmental standards have been established in the United States. 75% of the ash must have a fineness of 45 µm or less, and have carbon content, measured by the loss on ignition (LOI), of less than 4%. In the U.S., LOI needs to be under 6%. The particle size distribution of raw fly ash is very often fluctuating constantly, due to changing performance of the coal mills and the boiler performance. This makes it necessary that fly ash used in concrete needs to be processed using separation equipment like mechanical air classifiers.

2.2.1 Class C fly ash

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes.

Figure: 2.3 Section with Class C Fly Ash

(Source: U.S department of transportation, Federal Highway Administration)

2.2.2 Class F fly ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 10% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds. Alternatively, the addition of a chemical activator such as sodium silicate (water glass) to a Class F ash can lead to the formation of a geopolymer.

Figure: 2.4 Section with Class F Fly Ash

Source: U.S department of transportation, Federal Highway Administration

2.3 FEATURES

- **Spherical shape**: Fly ash particles are almost totally spherical in shape, allowing them to flow and blend freely in mixtures.
- **Ball bearing effect**: The "ball-bearing" effect of fly ash particles creates a lubricating action when concrete is in its plastic state.
- **Higher Strength**: Fly ash continues to combine with free lime, increasing structural strength over time.
- **Decreased Permeability** : Increased density and long term pozzolanic action of fly ash, which ties up free lime, results in fewer bleed channels and decreases permeability

  Increased Durability. Dense fly ash concrete helps keep aggressive compounds on the surface, where destructive action is lessened. Fly ash concrete is also more resistant to attack by sulfate, mild acid, soft (lime hungry) water, and seawater.
- **Reduced Sulfate Attack**: Fly ash ties up free lime that can combine with sulfate to create destructive expansion.
- **Reduced Efflorescence**: Fly ash chemically binds free lime and salts that can create efflorescence and dense concrete holds efflorescence producing compounds on the inside.
- **Reduced Shrinkage**: The largest contributor to drying shrinkage is water content. The lubricating action of fly ash reduces water content and drying shrinkage.

- **Reduced Heat of Hydration**: The pozzolanic reaction between fly ash and lime generates less heat, resulting in reduced thermal cracking when fly ash is used to replace portland cement.
- **Reduced Alkali Silica Reactivity**: Fly ash combines with alkalis from cement that might otherwise combine with silica from aggregates, causing destructive expansion.
- **Workability**: Concrete is easier to place with less effort, responding better to vibration to fill forms more completely.

  Ease of Pumping. Pumping requires less energy and longer pumping distances are possible.
- **Improved Finishing**: Sharp, clear architectural definition is easier to achieve, with less worry about in-place integrity.
- **Reduced Bleeding**: Fewer bleed channels decreases porosity and chemical attack. Bleed streaking is reduced for architectural finishes. Improved paste to aggregate contact results in enhanced bond strengths.
- **Reduced Segregation**: Improved cohesiveness of fly ash concrete reduces segregation that can lead to rock pockets and blemishes.
- **Reduced Slump Loss**: More dependable concrete allows for greater working time, especially in hot weather.

2.4 NATURE AND COMPOSITION

Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity. These micron-sized earth elements consist primarily of silica, alumina and iron. When mixed with lime and water the fly ash forms a cementitious compound with properties very similar to that of Portland cement.

Table: 2.2 Typical Chemistry of Coal Fly Ash (in Wt. %)

	ClassF*	**ClassF***	**ClassC***	**Class C***
	low-Fe	**high-Fe**	**high-Ca**	**low-Ca**
SiO_2	46-57	42-54	25-42	46-59
Al_2O_3	18-29	16.5-24	15-21	14-22
Fe_2O_3	6-16	16-24	5-10	5-13
CaO	1.8-5.5	1.3-3.8	17-32	8-16
MgO	0.7-2.1	0.3-1.2	4-12.5	3.2-4.9
K_2O	1.9-2.8	2.1-2.7	0.3-1.6	0.6-1.1
Na_2O	0.2-1.1	0.2-0.9	0.8-6.0	1.3-4.2
SO_3	0.4-2.9	0.5-1.8	0.4-5.0	0.4-2.5
LOI	0.6-4.8	1.2-5.0	0.1-1.0	0.1-2.3
TiO_2	1-2	1-1.5	<1	<1

There are substantial amount of non-combustible impurities present in coal in the form of limestone, shale, dolomite, feldspar and quartz. As the fuel travels through the high-temperature zone in the furnace, the volatile matter and carbon are burnt off whereas of the mineral impurities are carried of in the form of ash by the flue gas. The ash particles become fused in the combustion zone of the furnace; however on leaving the combustion zone of the furnace the molten ash is cooled rapidly and solidifies as spherical glassy particles. Some of the fused matter agglomerates to form bottom ash, but most of it flies out with the flue gas stream and is therefore called flyash.

The flyash is removed from the flue gas by means of a series of mechanical separators followed by electrostatic precipitators or bag filters. Typically the ratio of flyash to bottom ash is 70:30 in wet bottom boilers or 85:15 in dry bottom boilers

Table: 2.3 Chemical composition of fly ash

Component	Bituminous	Sub bituminous	Lignite
SiO_2 (%)	20-60	40-60	15-45
Al_2O_3 (%)	5-35	20-30	20-25
Fe_2O_3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

2.5 UTILIZATION

The reuse of fly ash as an engineering material primarily stems from its pozzolanic nature, spherical shape, and relative uniformity. Fly ash recycling, in descending frequency, includes usage in:

- Portland cement and grout
- Embankments and structural fill
- Waste stabilization and solidification
- Raw feed for cement clinkers
- Mine reclamation
- Stabilization of soft soils
- Road sub base
- Aggregate
- Flow able fill
- Mineral filler in asphaltic concrete

Other applications include cellular concrete, geopolymers, roofing tiles, paints, metal castings, and filler in wood and plastic products

2.6 COLLECTION

2.6.1 Ash Collection

Ash can be collected in following categories

- *Dry Fly Ash*

Dry ash is collected from different rows of electrostatic precipitators. It is available in two different grades of fineness in silos for use as resource material by different users.

- *Bottom Ash*

Bottom ash is collected from the bottom of the boiler and transported to hydro bins and then ash mound for use in road embankment.

- *Conditioned Fly Ash*

Conditioned fly ash is also available in ash mound for use in landfills and ash building products.

2.7 TRANSPORTATION

2.7.1 Fly Ash Transportation

Fly ash can be supplied in four forms:

- *Dry*: This is currently the most commonly used method of supplying fly ash. Dry fly ash is handled in a similar manner to Portland cement. Storage is in sealed silos with the associated filtration and desiccation equipment, or in bags.
- *Conditioned*: In this method, water is added to the fly ash to facilitate compaction and handling. The amount of water added being determined by the end use of the fly ash. Conditioned fly ash is widely used in aerated concrete blocks, grout and specialist fill applications.
- *Stockpiled*: Conditioned fly ash not sold immediately is stockpiled and used at a later date. The moisture content of stockpiled ash is typically 10 to 15%. This is used mainly in large fill and bulk grouting applications.
- *Lagoon*: Some power stations pump fly ash as slurry to large lagoons. These are drained and when the moisture content of deposited fly ash has reached a safe level may be recovered. Because of the nature of the disposal technique, the moisture content can vary from around 5% to over 30%. Lagoon fly ash can be used in similar applications to stockpiled conditioned fly ash.

2.7.2 CHALLENGES IN HANDLING FLY ASH

Many challenges have been reported in the handling and utilization of fly ash. Some of these difficulties include:

- The wet system of fly ash collection/disposal is the most common practice in India. Fly ash is mixed with bottom ash in slurry form before transporting it to ash ponds/lagoons. This process of fly ash dumping is largely unsuitable for all purposes where pozzolonic properties are essential to its use. Fineness and lime reactivity are seriously imparted and the ash from the ponds is unsuitable for use in most applications needing strength.
- Variations in ash composition are unavoidable and it largely depends on the quality of coal utilizes. Customer therefore can never therefore be sure of the quality of ash available from a particular source.
- There is no system of testing, labeling and packing of coal ash. Most of the ash producers are not equipped to certify the quality or specifications of an ash. This undermines the confidence of the end users of the fly ash from a particular source compelling them to set up such testing and other facilities at their own cost. This obviously makes them somewhat reluctant to use it.
- Most thermal stations are located in remote areas and the user industry faces difficulty in lifting and transporting the fly ash.

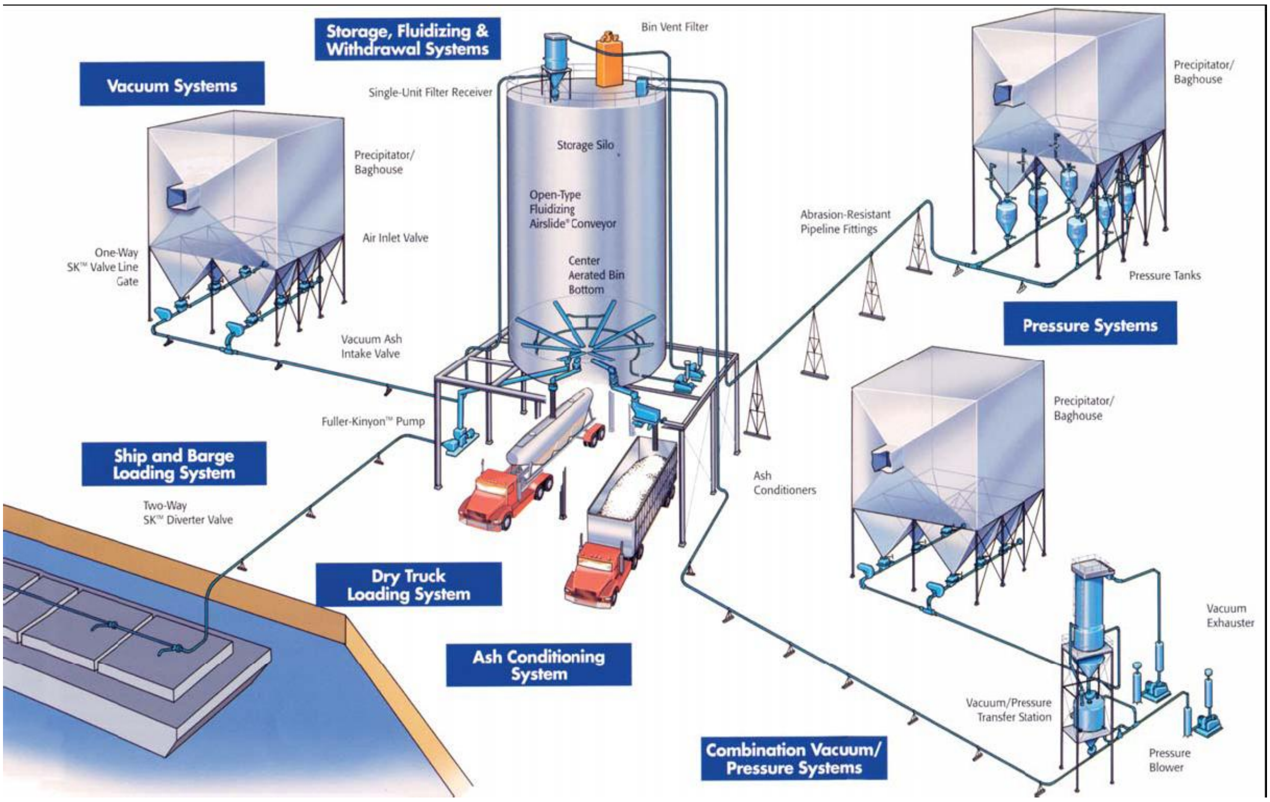


Figure: 2.5 Fly Ash Handling Systems

2.8 CHARECTERISTICS OF FLY ASH SLURRY

The ash is characterized by its physical (lightweight, small spherical particles, hardness) and chemical (cement-like) properties that gives it with an economic value as a raw material in many applications.

2.8.1 PHYSICAL PROPERTIES

Fly ash particles are very fine, light weight (density 1.97-2.89 g/cc) and spherical (specific surface area 4000-10,000 cm^2/g; diameter, 1-150µ), refractory and have pozzolanic ability. Fly ash grey to blackish grey and is dependent on coal type and combustion process. Fly ash has dielectric property (dielectric constant, 10^4) and can be used in electronic application.

2.8.2 CHEMICAL PROPERTIES

Chemical composition of fly ash is as follows: SiO_2, 59.38; Fe_2O_3, 6.11; CaO, 1.94; MgO, 0.97; SO_3, 0.76; alkalies, 1.41; and unburnt sulphur and moisture, 3.74%. According to ASTM C618 fly ash is classified into two classes (C & F) based on the amount of lime present. Class C lignite and sub-bituminous coal (>10% CaO) where as class F is bituminous or anthracite coal (<10% CaO). Oxides of silicon, aluminum, calcium and iron in fly ash are responsible for pozzolanic activity, which decreases by loss of ignition. Fly ash contain following toxic metals Hg, 1; Cd, Ga, Sb, Se, Ti and V, 1-10; As, Cr, La, Mo, Ni, Pb, Th, U and Zn, 10-100; and B, Ba, Cu, Mn and Sr, 100-1000 mg/kg. Heavy metals (As, Mo, Mn and Fe) show leaching with concentration above permissible limits.

2.9 FLY ASH MANAGEMENT

2.9.1 Eliminating Waste and Abating CO2 Emissions

Different methods of processing coal, different coal washery systems, clean coal technologies and particularly the development of ultra clean coal can, and do, have a dramatic effect on the quality and quantity of fly ash, generated by the combustion of pulverised coal. This type of solution, while reducing the problem of fly ash disposal, still leaves us with a problem of disposal of coal washery refuse, or some other form of processed coal waste. There are other potential possibilities for modifying the characteristics of fly ash to advantage, converting it from waste into a value added product. Two examples are increasing pozzolanicity and enhancing the cenosphere content of fly ash.

2.9.2 Increasing pozzolanicity

The pozzolanicity of fly ashes can vary widely. This reflects both the amount and nature of the mineral matter in the pulverised coals being used as fuel and the combustion conditions under which the fly ash is formed. It is believed that the production of fly ash of very high pozzolanicity is possible, without compromising the operation of a power station, through the judicious selection of appropriate coals or through slight modification of the chemical composition of the mineral matter present in the pulverised coal, and also through controlling the combustion process. Much higher Portland cement replacement rates with fly ash in concretes can be achieved using highly reactive ash, and still comply with the relevant Australian standards. Pozzolanic reactivity of fly ash is enhanced under steam-curing conditions. If concrete block manufacturing plants could be located near electric power stations, eliminating the need for transportation of ash and making full use of the available steam, again there could be a significant increase in the use of the fly ash.

2.9.3 Cenospheres

Most fly ashes contain a small proportion of thin-walled hollow spheres which are called 'cenospheres'. Many of these have a specific gravity less than one and when the fly ash is sluiced to the ash disposal dam they float and can be recovered as a value-added product. For example, cenospheres have been used as a filler in plastic and paint manufacturing and in the production of insulating refractories, which are known for their excellent strength to density ratios and for the thermal shock resistance. In Australia cenospheres after appropriate processing can fetch prices well when used in these applications.The cenosphere content of fly ashes varies from coal to coal and with combustion conditions (furnace load). If we can understand and control the factors responsible it should be possible to increase significantly the cenosphere content of selected fly ashes, again without compromising the operation of a power station for electricity production. If the amount of cenospheres in fly ash can be increased significantly, and hence become available in sufficient quantities on a reliable long-term basis, at a reduced unit cost, a range of excellent lightweight building materials and other products can be manufactured at a competitive market price.

Very large volumes of fly ash can be used in manufacturing special slurries for diaphragm walls and land reclamation, in underground mining, in special grouts, and for the encapsulation of hazardous wastes and for the decommissioning of underground fuel tanks.

Chapter 3

MECHANISM AND MATERIAL

MATERIALS AND METHODS

SAMPLE COLLECTION

SETTLING CHARACTERISTIC

PHYSICOCHEMICAL PROPERTIES

MOISTURE CONTENT

TRUE DENSITY

SPECIFIC GRAVITY

PARTICLE SIZE DISTRIBUTION

BET- SURFACE AREA METHOD

SLUMP TEST

SEM (SCANNING ELECTRON MICROSCOPE)

3.1 MATERIALS AND METHODS

The study of the physicochemical and engineering properties of fly ash is necessary to understand the variation in the properties of fly ash In the Indian context, in order to utilize the same as large volume backfill media. In addition to this the study is required to establish properties such as permeability, particle size distribution, and morphological characteristics of the fly ash which influence the settling behavior and flow properties during hydraulic transportation.

3.1.1SAMPLE COLLECTION

Fly ash is a fine, powdery material that is produced by burning coal to produce electricity, primarily in pulverized coal combustion (PCC) boilers. It is composed mainly of non-combustible inorganic material, but also contains some carbon that is leftover from partially combusted coal. Although fly ash particles are generally largely spherical in shape, there are usually irregularly-shaped particles present also, such as angular particles of quartz. The spherical shape of fly ash results from the formation of tiny molten droplets as the ash travels through the boiler. The droplets form spheres because this shape minimizes the surface area relative to the volume. Since it is so fine, removal and collection of fly ash from combustion gases (flue gas) requires specialized equipment such as electrostatic precipitators or fabric filters.

The sample collection of different types of ashes such as fly ash, bottom ash and pond ash has different procedures. The fly ash and the bottom ashes are generated at the power plant and can be collected directly from the discharge points. In most of the power plants sampling pipes are provided at places near the discharge point or near the storage point for collection of ash samples. The sample can be directly collected into a bucket or any other container and can be suitable packed for transportation.

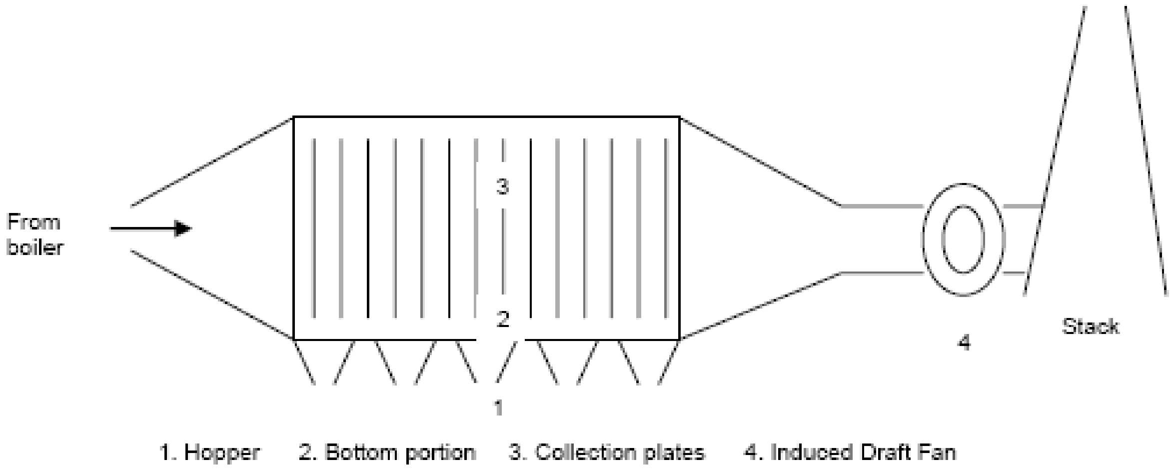


Figure: 3.1 sampling location in the ESP

Figure: 3.2 Fly ash (class C) sample as taken from an ash impoundment

Figure: 3.3 Fly ash (class F) sample as taken from an ash impoundment

Sample from Jindal Steel Plant

The sample was collected from Jindal Steel Plant, from near the hopper of the power plant. The fly ash sample collected was dark grey in color. The sample was collected in a sack.

3.2 SETTLING PROPERTIES

Tests on settling rates establish the ease with which solid-liquid separation takes place in slurries during filling activity, and the tests also provide a means of determining the recycled water quality.

Experimental procedure:

Take a measuring jar graduated in ml. clean it thoroughly with pure water. Take water into the flask up to certain level (x ml) and then add fly ash (100-x ml) slowly into the jar. Mix the water and fly ash thoroughly with a stirrer for some time. Note down upper and lower meniscus of the mixture. Then note down time for each ml settling of fly ash in water. Repeat the other sample and tabulate the results.

Table: 3.1 Sample name: F50W50 settling characteristic

Time (hrs)	Upper level reading (ml)	Lower level reading (ml)
2.45	74	72
2.50	74	71
3.02	74	70
3.14	74	69
3.25	74	68
3.37	74	67
3.47	74	66
3.56	74	65
4.07	74	64
4.16	74	63
4.24	74	62
4.32	74	61
4.40	74	60
4.49	74	59
4.59	74	58
5.12	74	57
5.28	74	56
6.00	74	55

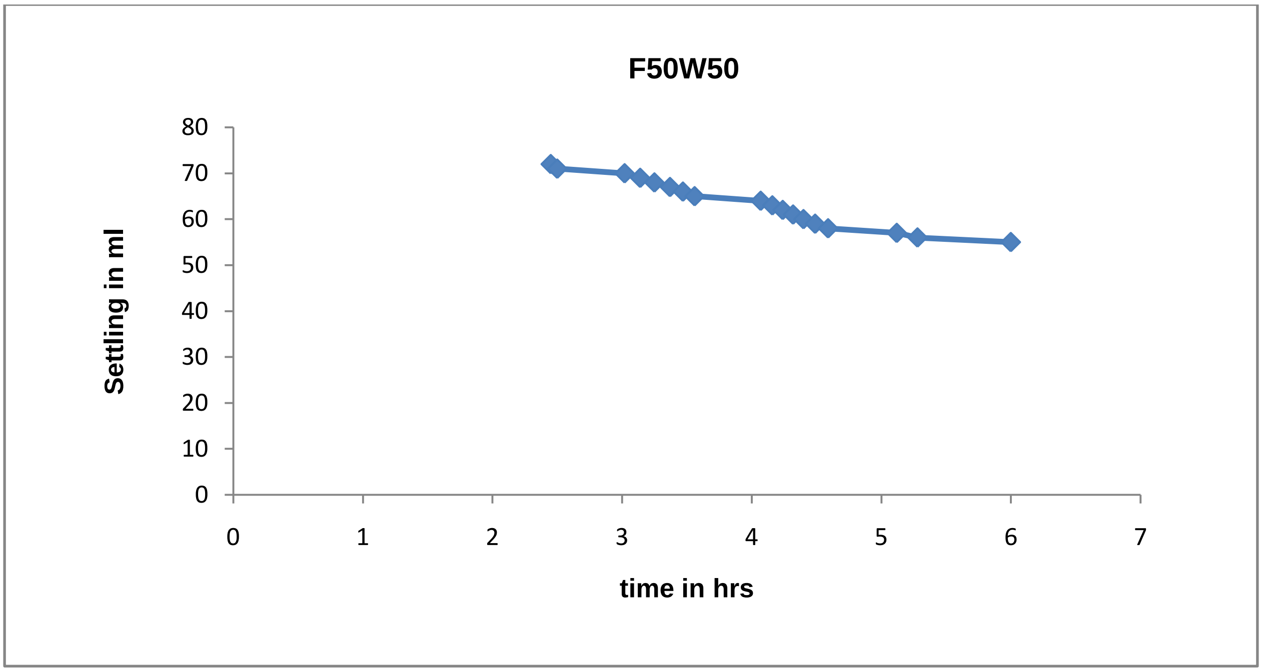


Figure: 3.4 settling characteristic graph of F50W50

Table: 3.2 Sample name: F25W75 settling characteristic

Time (hrs)	Upper level reading (ml)	Lower level reading (ml)
2.06	87	84
2.06	87	83
2.07	87	82
2.07	87	81
2.08	87	80
2.09	87	79
2.10	87	78
2.10	87	77
2.11	87	76
2.12	87	75
2.12	87	74
2.13	87	73
2.14	87	72
2.15	87	71
2.15	87	70
2.16	87	69
2.17	87	68
2.17	87	67
2.18	87	66
2.19	87	65
2.20	87	64
2.21	87	63

2.22	87	62
2.23	87	61
2.23	87	60
2.24	87	59
2.25	87	58
2.26	87	57
2.27	87	56
2.28	87	55
2.29	87	54
2.30	87	53
2.31	87	52
2.32	87	51
2.33	87	50
2.34	87	49
2.36	87	48
2.37	87	47
2.39	87	46
2.40	87	45
2.42	87	44
2.44	87	43
2.46	87	42
2.49	87	41
2.51	87	40
2.54	87	39
2.57	87	38
3.01	87	37
3.05	87	36
3.11	87	35
3.18	87	34
3.25	87	33
3.35	87	32
3.54	87	31
7.00	87	30

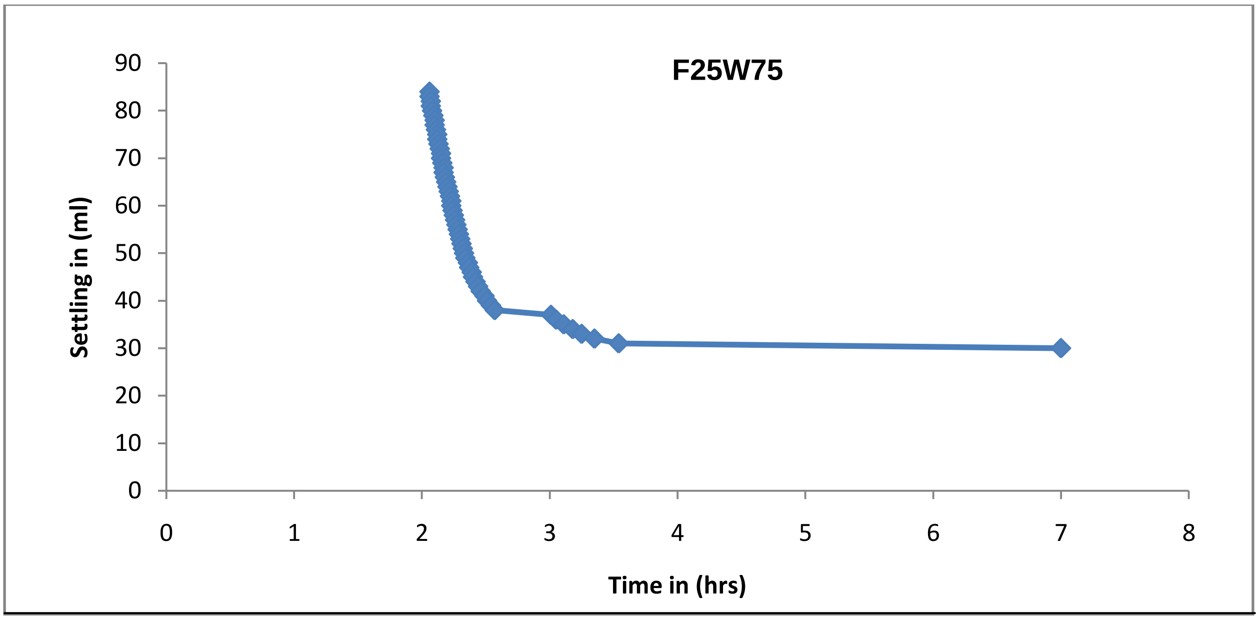


Figure: 3.5 settling characteristic graph of F25W75

Table: 3.3 Sample name: F40W60 settling characteristic

Time (hrs)	Lower level reading (ml)	Upper level reading (ml)
2.04	78	79
2.06	77	79
2.11	76	79
2.14	75	79
2.18	74	79
2.22	73	79
2.25	72	79
2.28	71	79
2.32	70	79
2.35	69	79
2.38	68	79
2.42	67	79
2.45	66	79
2.48	65	79
2.51	64	79
2.55	63	79
2.59	62	79
3.02	61	79

3.05	60	79
3.09	59	79
3.12	58	79
3.15	57	79
3.19	56	79
3.22	55	79
3.27	54	79
3.30	53	79
3.35	52	79
3.40	51	79
3.45	50	79
3.51	49	79
3.58	48	79
4.08	47	79
4.24	46	79
4.51	45	79

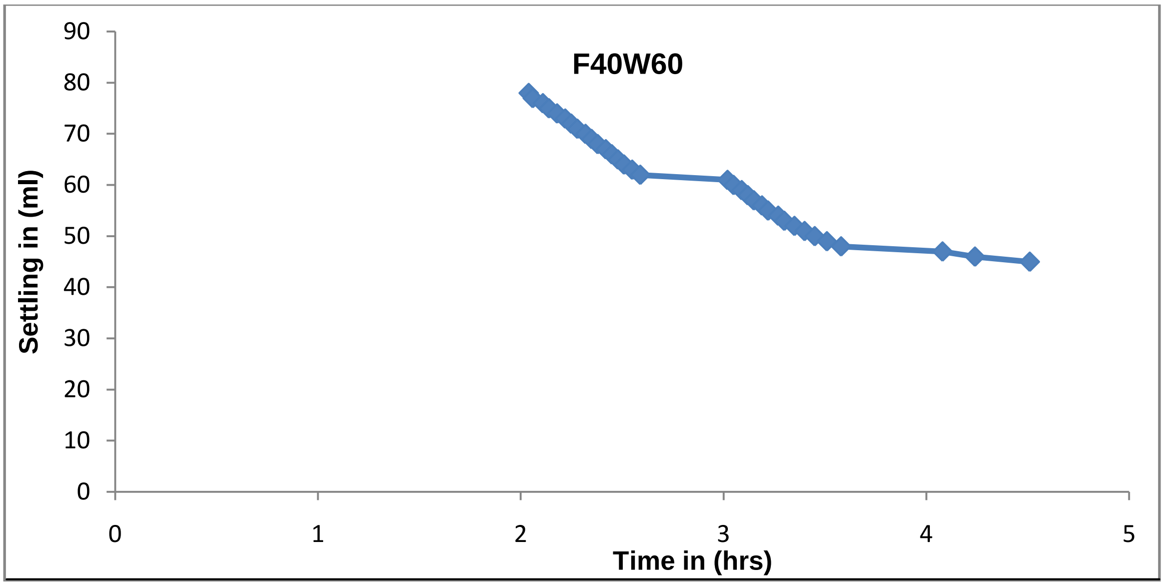


Figure: 3.6 settling characteristic graph of F40W60

Table: 3.4 Sample name: F35W65 settling characteristic

Time (hrs)	Upper level reading (ml)	Lower level reading (ml)
1.48	82	80
1.49	82	79
1.50	82	78
1.53	82	77
1.55	82	76
1.57	82	75
1.59	82	74
2.02	82	73
2.04	82	72
2.06	82	71
2.08	82	70
2.11	82	69
2.13	82	68
2.15	82	67
2.18	82	66
2.20	82	65
2.22	82	64
2.24	82	63
2.27	82	62
2.29	82	61
2.31	82	60
2.33	82	59
2.35	82	58
2.37	82	57
2.40	82	56
2.42	82	55
2.45	82	54
2.47	82	53
2.50	82	52
2.53	82	51
2.55	82	50
2.58	82	49
3.02	82	48

3.06	82	47
3.09	82	46
3.13	82	45
3.18	82	44
3.24	82	43
3.32	82	42
3.41	82	41
3.55	82	40
4.28	82	39

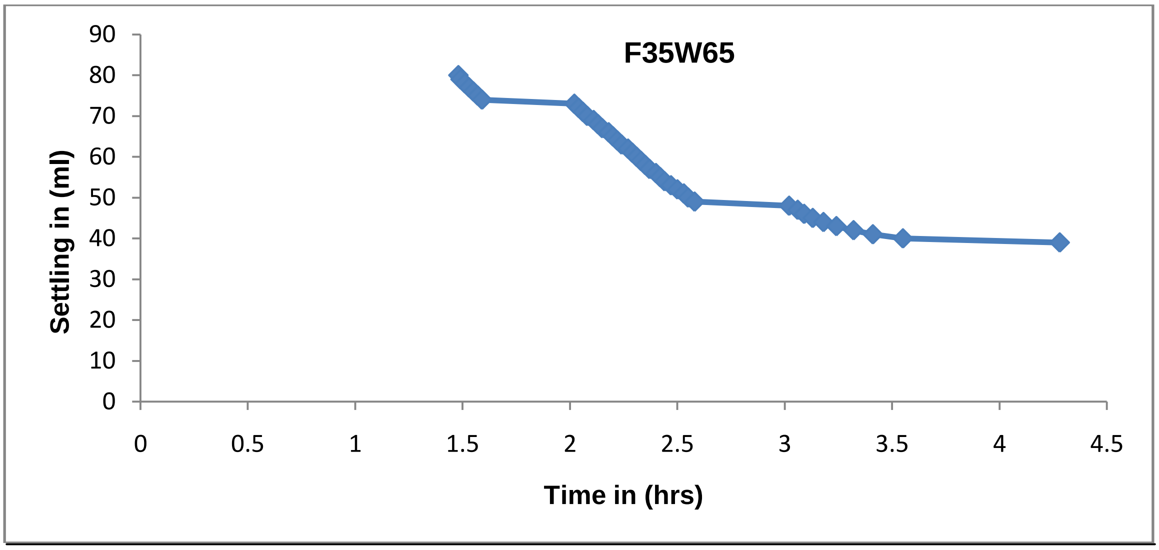


Figure: 3.7 settling characteristic graph of F35W65

Figure: 3.8 Experimental set up for settling characteristic of fly ash

3.3 PHYSICOCHEMICAL PROPERTIES

Collected fly ash samples are examined under the different processes to know the major physicochemical properties and settling properties of all the samples. The properties studies are chemical composition, particle, size distribution, specific gravity, true density.

3.3.1 MOISTURE CONTENT

Coal due it its nature, origin and occurrence is always associated with same amount of moisture, which is both physically and chemically bound. It is customary to differentiate between external and inherent moisture. When a wet fly ash is exposed to atmosphere, the external atmosphere evapourates, but the apparently dry fly ash still contains some moisture, which can be removed only on heating above 100^{o}C. External moisture is also called accidental or free moisture where as inherent moisture is termed as equilibrium or air dried or hygroscopic moisture. The quantity of external moisture depends mainly on the mode of occurrence and handling of fly ash, but the air-dried moisture is related to the inherent hygroscopic nature of the fly ash.

Test procedure

About 1 gm of finely powdered (-212 micron) air-dried fly ash sample is weighed in a silica crucible and then placed inside an electric hot air oven, maintained at $108^0 \pm 2^0C$. The crucible with the fly ash sample is allowed to remain in the oven for 1.5 hours and is then taken out with a pair of tongs, cooled in desiccators for about 15 minutes and then weighed. The loss in weight is reported as moisture (on % basis). Then calculation is done as per the following.

% moisture = $Y-Z/Y-X$

Where X= weight of empty crucible, gram

Y= weight of crucible + fly ash sample before heating, gram

Z= weight of crucible + fly ash sample after heating, gram

$Y-X$= weight of fly ash sample, gram

$Y-Z$= weight of moisture

Table: 3.5 MOISTURE CONTENT OF FLY ASH

Weight of empty crucible(gm)	Weight of fly ash (gm)	Weight of crucible and fly ash before heating (gm)	Weight of crucible and fly ash after heating (gm)	Moisture content (%)	Average moisture content (%)
15.236	1.001	16.237	16.102	0.135	**0.175**
15.125	1.005	16.130	15.914	0.210	
16.856	1.004	16.860	16.679	0.180	

3.3.2 TRUE DENSITY

True density of fly ash is the weight per unit volume of very finely powdered sample. Therefore, the volume of pores spaces and the interspaces is not included here. To determine the true density, fly ash sample is dispersed in water. The amount of water dispersed per gram of fly ash gives the true density of fly ash. The density of the fly ash, which ranges from 2-2.8, determines the volume it will occupy for a given mass. Density changes may indicate a different coal source.

Test procedure

Take a measuring jar graduated in ml. clean it thoroughly with pure water. Take water into the flask up to certain level and note down its level (initial reading). Drop slowly 20 grams of the supplied fly ash sample into the jar. Shake the jar for some time. Now note down the level of eater in the jar (final reading). Repeat this for 4 samples and tabulate the results. Divide the difference of the final and initial reading by weight of the sample to obtain true density.

Table: 3.6 TRUE DENSITY OF FLY ASH

SL NO	Amount of fly ash taken (gm)	Initial reading in (ml)	Final reading in (ml)	Difference in (ml)	True Density in (gm/cc)	Average true density
1	20	80	89	9	2.23	**2.29**
2	20	80	88	8	2.5	
3	20	81	90	9	2.23	
4	20	81	90	9	2.23	

3.3.3 SPECIFIC GRAVITY

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. The specific gravity of a fly ash is used in the phase relationship of air, water and solids in a given volume of the fly ash.

Test procedure

Determine and record the weight of the empty clean and dry pycnometer, W_P. Place 10g of a dry fly ash sample (passed through the sieve No. 10) in the pycnometer. Determine and record the weight of the pycnometer containing the dry fly ash, W_{PS}. Add distilled water to fill about half to three-fourth of the pycnometer. Soak the sample for 10 minutes. Apply a partial vacuum to the contents for 10 minutes, to remove the entrapped air. Stop the vacuum and carefully remove the vacuum line from pycnometer. Fill the pycnometer with distilled (water to the mark), clean the exterior surface of the pycnometer with a clean, dry cloth. Determine the weight of the pycnometer and contents, W_B. Empty the pycnometer and clean it. Then fill it with distilled water only (to the mark). Clean the exterior surface of the pycnometer with a clean, dry cloth. Determine the weight of the pycnometer and distilled water, W_A. Empty the pycnometer and clean it.

Calculate the specific gravity of the fly ash using the following formula:

Specific Gravity, $G_s = W_o/W_o + (W_A - W_B)$

Where:

W_0 = weight of sample of oven-dry fly ash, g = $W_{PS} - W_P$

W_A = weight of pycnometer filled with water

W_B = weight of pycnometer filled with water and fly ash

Table: 3.7 SPECIFIC GRAVITY OF FLY ASH

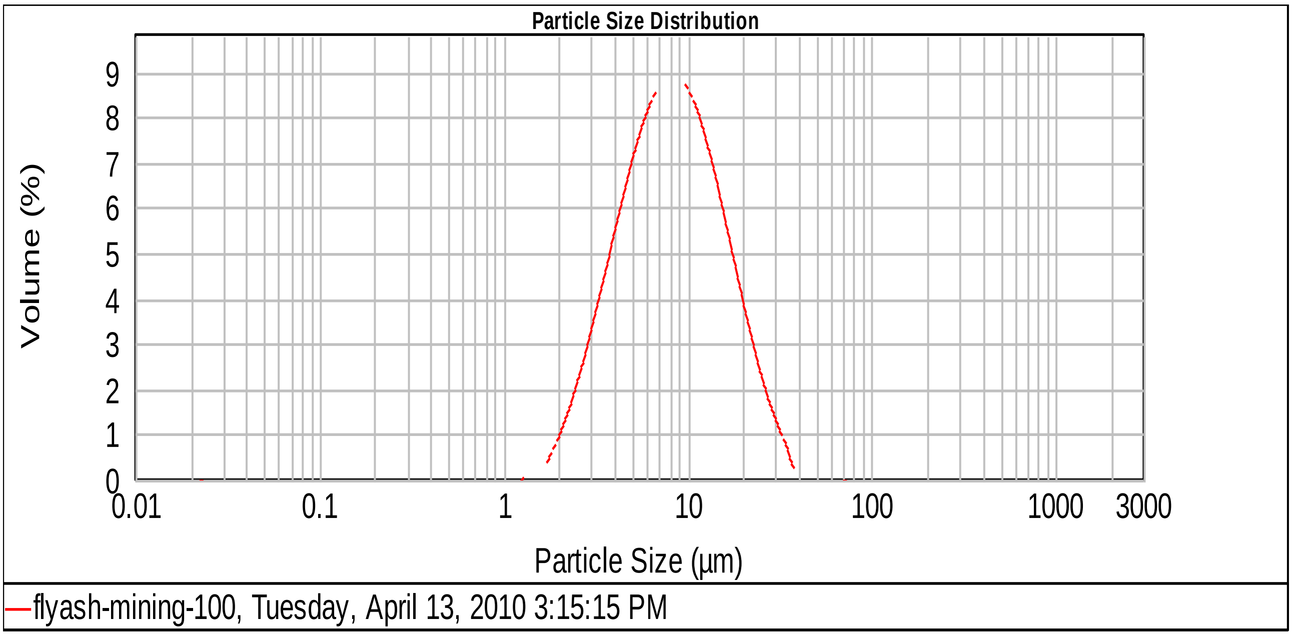
Sl.no.	Mass of empty, clean pycnometeter (W_P), (grams)	Mass of empty pycnometer + dry fly ash (W_{PS}), (grams)	Mass of pycnometer + dry fly ash + water (W_B),(grams)	Mass of pycnometer + water (W_A), (grams)	Specific gravity (G_S)	Average Specific gravity
1	41.69	73.42	157.28	139.38	2.294	**2.275**
2	49.93	79.67	157.29	142.40	2.254	

3.3.4 PARTICLE SIZEDISTRIBUTION

The particle size distribution (PSD) of a powder, or granular material, or particles dispersed in fluid, is a list of values or a mathematical function that defines the relative amounts of particles present, sorted according to size. PSD is also known as grain size distribution.

Particle Size: A better indication of the fineness is to determine the particle size distribution. For example, one can determine the mass percentage below 10 um or determine the mean particle diameter. The particle size of fly ash varies from below 1 um to 200 um or more. Thus a fly ash might have the following distribution (on a mass basis): 0.3-2 % below 1 um, 30-70 % finer than 10 um, 0.5-7 % above 100 um and 0-2 % above 200 um. It should be noted that to increase the Strength Activity Index (ASTM C 618) one can air-classify or grind the fly ash to improve its fineness. On a numerical basis: 40-60% of total numbers of particles are from 0-1 um. This is more significant with regards to greater surface area for pozzolanic reactions and leaching potential of trace metals.

The particle size of the fly ashes was measured using a laser based particle size analyzer, namely a Mastersizer 2000 of Malvern Instruments Ltd. It utilizes Fraunhofer diffraction of light formed by particles with a diameter larger than the incident laser beam wavelength. A combination of an optical filter, lens and photo detector coupled with a computer loaded with Mastersizer software enables one to compute the particle size distribution from the diffraction data and store it as volume percentage against the particle size.



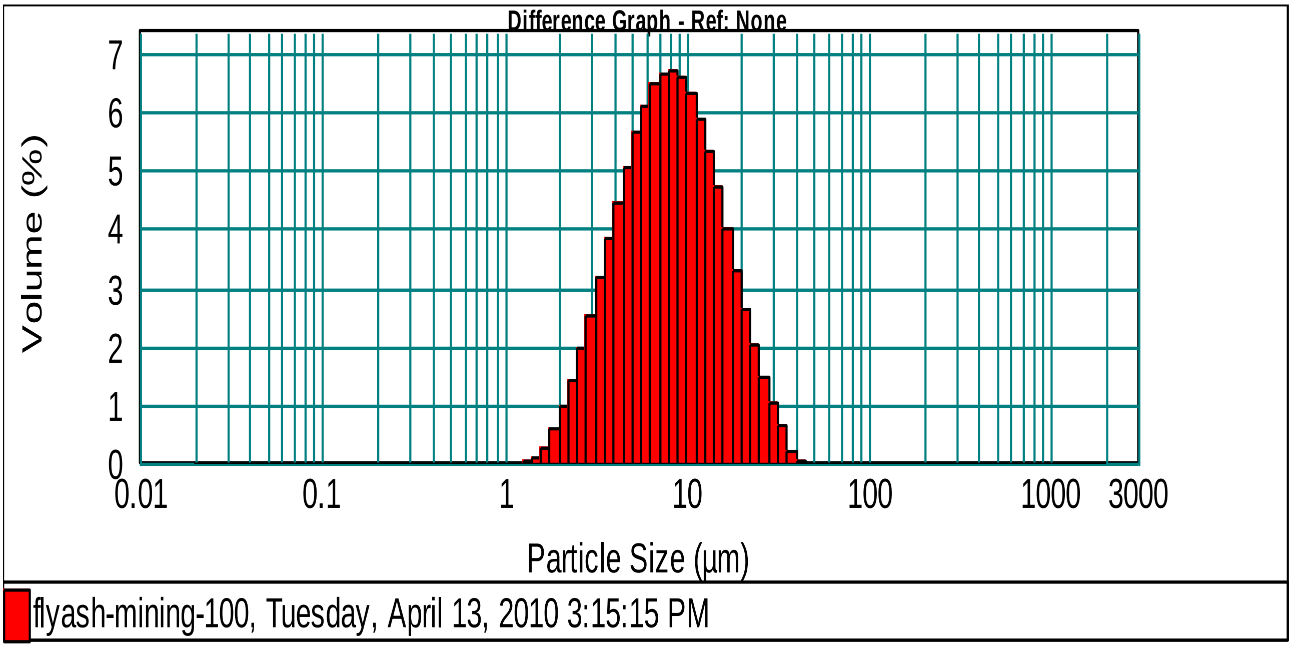


Figure: 3.9 Particle size distribution of fly ash

PARTICLE SIZE

- Minimum-3.44 um
- Mean-8.080 um
- Maximum-18.585 um

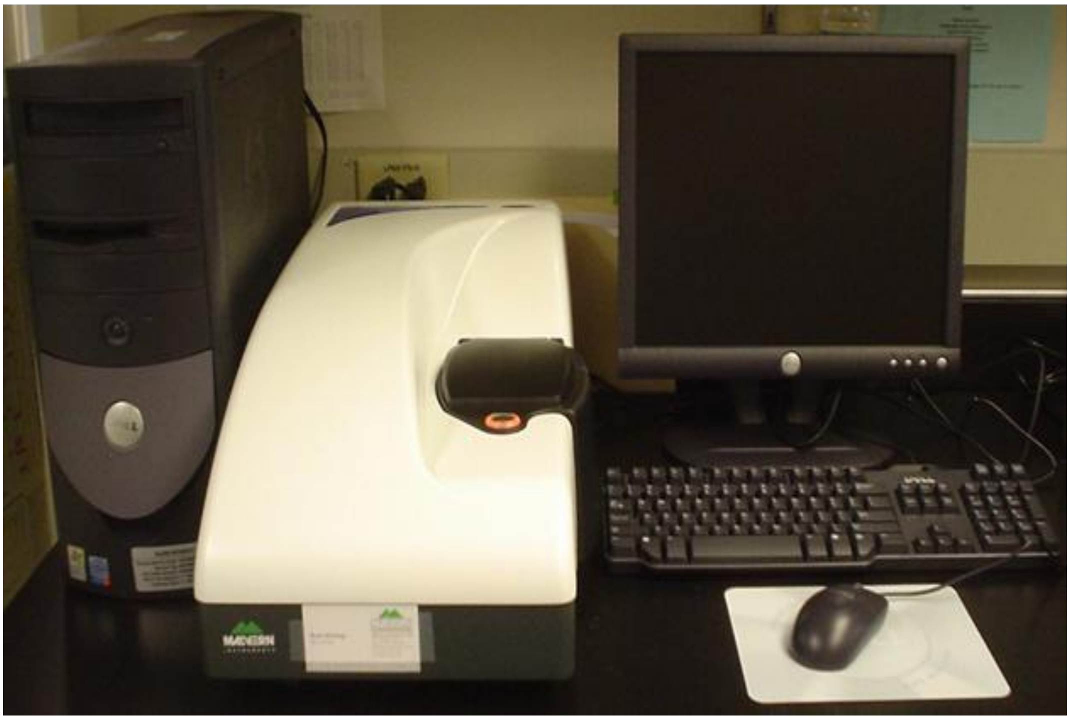


Figure: 3.10 Dynamic Light Scattering Zeta Sizer: Malvern Instrument

Definition

A suspension of powder in isopropanol is measured with a low angle laser beam, and the particle size distribution is calculated.

Scope

This is a fast method for measuring particle size distribution of powders.

Principle

The method can be used on all powders containing less than 10% fat.

Apparatus

- Malvern Instrument, Mastersizer Basic, equipped with software version B.0 or similar equipment.
- Malvern QS Small Volume Sample Dispersion Unit.
- Malvern in/out measuring cell, beam length 2.0 mm.
- Dispenser 0-50 ml with container.
- Filling knife.
- Waste container.

Reagents

- Isopropanol, IPA (technical quality).

Procedure

- Look at the particle size in a microscope and choose a lens capable of measuring the largest particles.
- Prepare the instrument for measuring in wet mode using IPA as the liquid, as described in the user manual.
  The stirrer regulator should be set at 2000 rpm on the Malvern unit.
- Measure the background for IPA.
- Quickly add a sufficient amount of milk powder and measure as soon as the powder is dispersed and not later than 20 seconds after addition of the powder. For detailed instructions about measuring, see the Malvern user manual.
- Rinse twice with IPA.

All measurements are made in duplicate

Result

The following calculations are done automatically:

- The volume median diameter D (v, 0.5) is the diameter where 50% of the distribution is above and 50% is below.
- Two determinations of mean particle size should not differ by more than 5% relative. The shape of the curves in the two determinations should be the same.
- D (v, 0.9), 90% of the volume distribution is below this value.
- D (v, 0.1), 10% of the volume distribution is below this value.
- The span is the width of the distribution based on the 10%, 50% and 90% quantile.

$$\text{Span} = \frac{D\,[v, 0.9] - D\,[v, 0.1]}{D\,[v, 0.5]}$$

3.3.5 BET- SURFACE AREA METHOD

Specific surface area is defined as the ratio A / m (unit: m2/g) between the absolute surface area of a solid and its mass (sample weight). The surface area includes all parts of accessible inner surfaces (mainly pore wall surfaces).

BET theory

BET theory is a rule for the physical adsorption of gas molecules on a solid surface and serves as the basis for an important analysis technique for the measurement of the specific surface area of a material.

The concept of the theory is an extension of the Langmuir theory, which is a theory for monolayer molecular adsorption, to multilayer adsorption with the following hypotheses: (a) gas molecules physically adsorb on a solid in layers infinitely; (b) there is no interaction between each adsorption layer; and (c) the Langmuir theory can be applied to each layer. The resulting **BET equation** is expressed by

$$v = v_m cp/ (p_0 - p) \{1+(c-1) (p/p_0)\} \ldots\ldots.. (1)$$

A more convenient form is the following:

$$p/v (p_0 - p) = 1/v_m c + c - p/v_m c (p/p_0)$$

p and p_0 are the equilibrium and the saturation pressure of adsorbates at the temperature of adsorption, v is the adsorbed gas quantity (for example, in volume units), and v_m is the monolayer adsorbed gas quantity. c is the BET constant, which is expressed by

$$c = \exp (E_1 - E_L)/ RT$$

E_1 is the heat of adsorption for the first layer, and E_L is that for the second and higher layers and is equal to the heat of liquefaction.

Plot a straight line with $1 / v[(P_0 / P) - 1]$ on the y-axis and $\varphi = P / P_0$ on the x-axis according to experimental results. This plot is called a **BET plot**. The linear relationship of this equation is maintained only in the range of $0.05 < P / P_0 < 0.35$. The value of the slope A and the y-intercept I of the line are used to calculate the monolayer adsorbed gas quantity v_m and the BET constant c. The following equations can be used:

$$v_m = 1/ A+I$$

$$c = 1+A/I$$

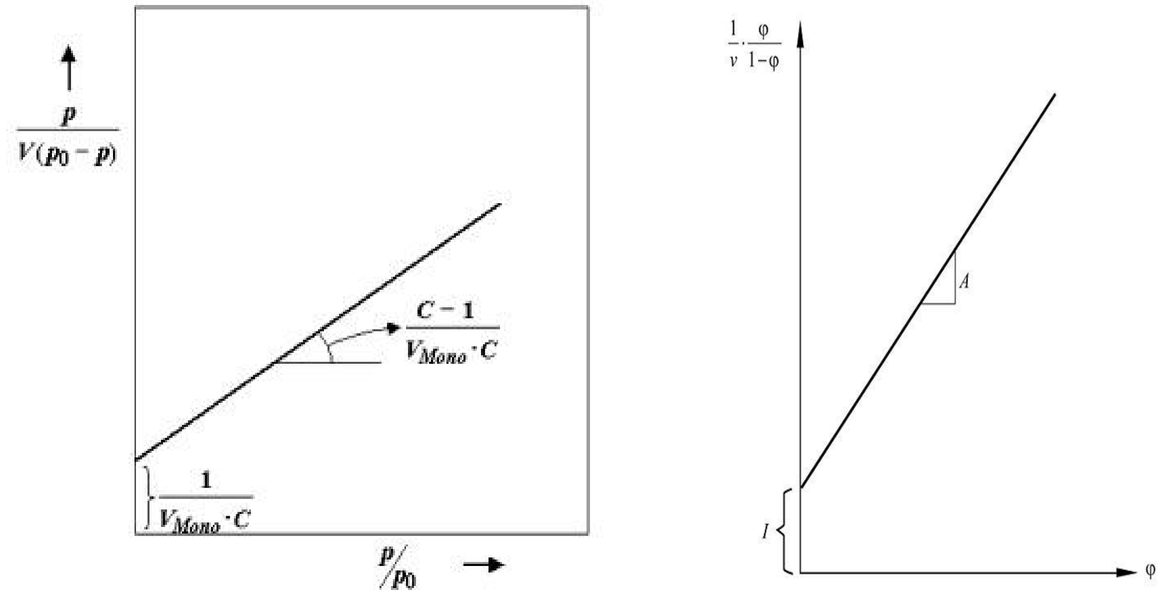


Figure: 3.11 BET plot

The BET method is widely used in surface science for the calculation of surface areas of solids by physical adsorption of gas molecules. A total surface area S_{total} and a specific surface area *S* are evaluated by the following equations:

$$S_{BET,\ total} = v_m Ns/V$$

$$S_{BET} = S_{total}/a$$

N: Avogadro's number

s: adsorption cross section

V: molar volume of adsorbent gas

a: molar weight of adsorbed species

Principle of the method

The BET method involves the determination of the amount of the adsorbate or adsorptive gas required to cover the external and the accessible internal pore surfaces of a solid with a complete monolayer of adsorbate. This monolayer capacity can be calculated from the adsorption isotherm by means of the BET equation.

The gases used as adsorptives have to be only physically adsorbed by weak bonds at the surface of the solid (van der-Waals forces) and can be desorbed by a decrease of pressure at the same temperature. The most common gas is nitrogen at its boiling temperature (77.3 K). In the case of a very small surface area (below 1 m^2/g), the sensitivity of the instruments using nitrogen is insufficient and krypton at 77.3 K should be used.

In order to determine the adsorption isotherm volumetrically, known amounts of adsorptive are admitted stepwise into the sample cell containing the sample previously dried and outgassed by heating under vacuum. The amount of gas adsorbed is the difference of gas admitted and the amount of gas filling the dead volume (free space in the sample cell including connections). The adsorption isotherm is the plot of the amount gas adsorbed (in mol/g) as a function of the relative pressure p/p_0.

Adsorption

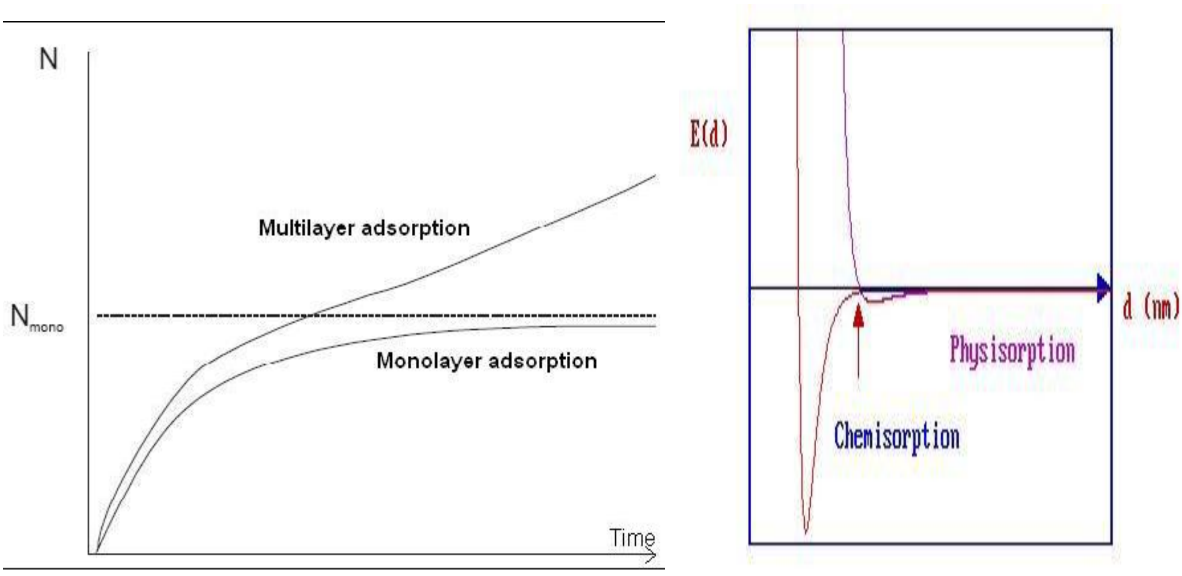


Figure: 3.12 Adsorption isotherm graph

Physisorption, determined by:

- Temperature
- Gas pressure
- Interaction between surface and gas (e.g vapor pressure)
- Surface area

Monolayer adsorption: Langmuir isotherm

Multilayer adsorption: BET theory

The specific surface area of a fly ash is estimated from the amount of nitrogen adsorbed in relationship with its pressure, at the boiling temperature of liquid nitrogen under normal atmospheric pressure. The observations are interpreted following the model of Brunauer, Emmett and Teller (BET Method).

The BET method is widely used in surface science for the calculation of surface areas of flyash by physical adsorption of gas molecules.

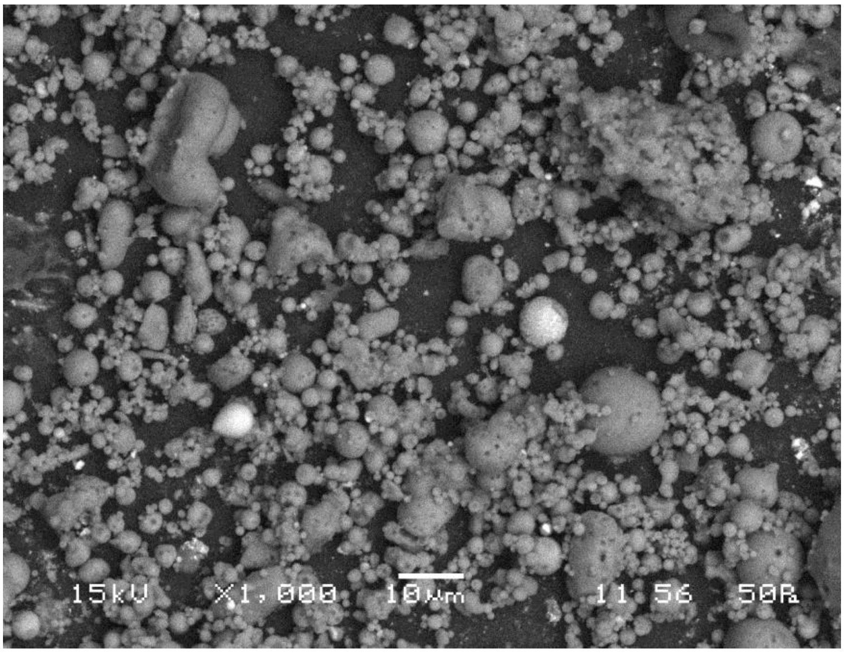
3.3.6 SEM (Scanning Electron Microscope)

The **scanning electron microscope** (**SEM**) is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the sample's surface topography, composition and other properties such as electrical conductivity.

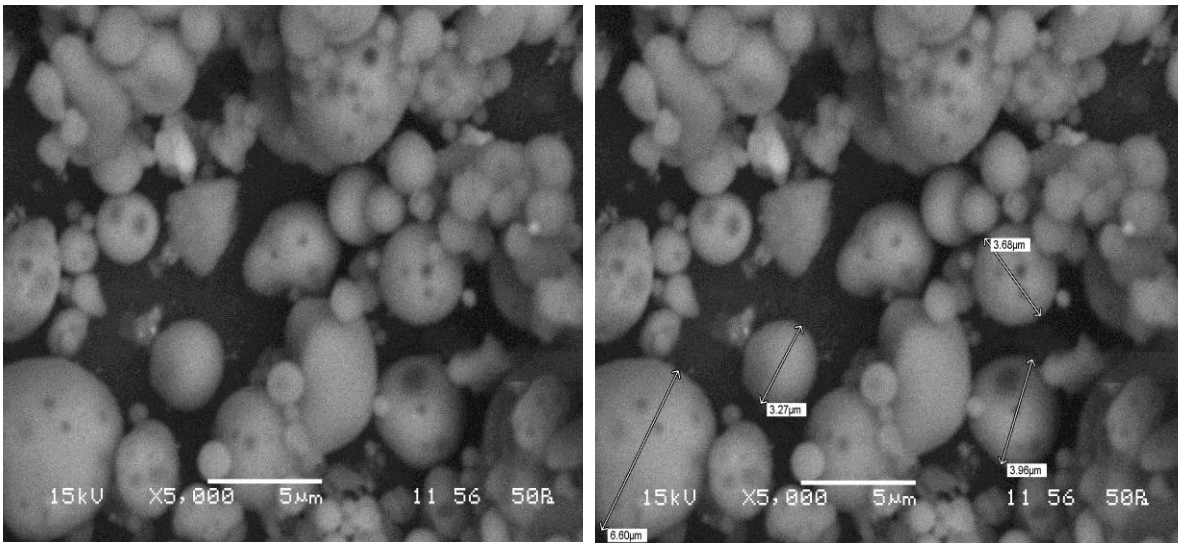
The types of signals produced by an SEM include secondary electrons, back-scattered electrons (BSE), characteristic X-rays, light (cathodoluminescence), specimen current and transmitted electrons. Secondary electron detectors are common in all SEMs, but it is rare that a single machine would have detectors for all possible signals. The signals result from interactions of the electron beam with atoms at or near the surface of the sample. In the most common or standard detection mode, secondary electron imaging or SEI, the SEM can produce very high-resolution images of a sample surface, revealing details about less than 1 to 5 nm in size. Due to the very narrow electron beam, SEM micrographs have a large depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample. A wide range of magnifications is possible, from about 10 times (about equivalent to that of a powerful hand-lens) to more than 500,000 times, about 250 times the magnification limit of the best light microscopes. Back-scattered electrons (BSE) are beam electrons that are reflected from the sample by elastic scattering. BSE are often used in analytical SEM along with the spectra made from the characteristic X-rays. Because the intensity of the BSE signal is strongly related to the atomic number (Z) of the specimen, BSE images can provide information about the distribution of different elements in the sample. Characteristic X-rays are emitted when the electron beam removes an inner shell electron from the sample, causing a higher energy electron to fill the shell and release energy. These characteristic X-rays are used to identify the composition and measure the abundance of elements in the sample.

Chemical analysis in the scanning electron microscope is performed by measuring the energy or wavelength and intensity distribution of x-ray signal generated by a focused electron beam on the specimen. With the attachment of the energy dispersive spectrometer (EDS) or wavelength dispersive spectrometer (WDS) the precise elemental composition of material can be obtained with high spatial resolution. When we work with bulk specimen in the SEM very precise accurate chemical analysis (relative error- 1-2%) can be obtained from larger areas of the solid (0.5-3 µm dia) using an EDS or WDS.

Figure: 3.13 SEM MICROPHOTOGRAPHS OF FLY ASH UNDER DIFFERENT MAGNIFICATION



Magnification at 1000x



Magnification at 5000x

3.4 SLUMP TEST (ASTM Method C143 CAN3-A23.2-M77)

Determining the consistency of concrete by filling a conical mold with a sample of concrete, then inverting it over a flat plate and removing the mold; the amount by which the concrete drops below the mold height is measured and this represents the slump.This test method describes the procedure for determining the slump of fresh concrete mixtures.

Test Procedure

- Dampen the mold and place it on a flat, moist, non-absorbent rigid surface.
- Hold firmly in place by standing on the two foot pieces.
- Fill the cone 1/3 full and uniformly rod the layer 25 times to its full depth.
- Fill the cone with a second layer until 2/3 full by volume and rod 25 times uniformly, ensuring that the rod just penetrates into the first layer.
- Overfill the cone with the third layer and rod uniformly, 25 times, with the rod just penetrating into the second layer.
- Strike off the excess concrete level with the top of the cone by a screening and rolling motion of the tamping rod.

- Remove any spilled fly ash from around the bottom of the cone.
- Immediately remove the mold from the fly ash by raising it carefully in a vertical direction without lateral or torsional motion.
- Measure the difference between the height of the mold and the height of the specimen at its highest point to the nearest 6.3 mm. This distance will be the slump of the fly ash.

CHAPTER-4

RESULT AND DISCUSSION

CONCLUSION

4.1 RESULTS & DISCUSSION

4.1.1 SEM (Scanning Electron Microscope)

The SEM data indicated intermixing of Fe and Al-Si mineral phases and the predominance of Ca non-silicate minerals**.** The fly ash samples consisted mainly of amorphous alumino-silicate spheres with a lesser number of iron-rich spheres. The majority of the iron-rich spheres consisted of two phases: an iron oxide mixed with amorphous alumino-silicate. The calcium-rich material was distinct in both elemental composition and texture from the amorphous alumino-silicate spheres. It was clearly a non-silicate mineral possibly calcite, lime, gypsum or anhydrite. In spite of the inherent variability of fly ash samples, this analysis indicated that the primary mineral/morphological structures are fairly common. Quartz and alumino-silicates are found as crystals and as amorphous particles.

4.1.2 SPECIFIC GRAVITY (ASTM D 854)

The specific gravity of the fly ash collected from Jindal Steel Plant was found to be 2.275.

4.1.3 TRUE DENSITY

The true density of fly ash collected from Jindal Steel plant was found to be 2.29**.**

4.1.4 MOISTURE CONTENT

The moisture content of fly ash collected from Jindal Steel Plant was found to be 0.175%. The moisture content of the sample were found out to be around 0.175% indicating that all the moisture have been evacuated and they are suitable for the construction works etc.

4.1.5 SPECIFIC SURFACE AREA

The specific BET surface area of the fly ash collected from the Zindal Steel Plant was found to be 0.44 square meter per gram.

4.1.6 PARTICLE SIZE ANALYSIS

The particle size of fly ash collected from Jindal steel plant was found to be

Minimum-3.44 µm Mean-8.080 µm Max-18.585 µm

The size, density, type of reinforcing particles and its distribution have a pronounced effect on the properties of particulate composite. The size range of the particles is very wide i.e. 0.1 micron to 100 micron. The size ranges of the fly ash particles indicate that the composite prepared can be considered as dispersion strengthened as well as particle reinforced composite. Thus the strengthening of composite can be due to dispersion strengthening as well as due to particle reinforcement.

4.1.7 SETTLING CHARACTERISTICS OF FLY ASH

Fly ash: 40 gm and water: 60ml

Upper reading: 79 ml, lower reading: 78 ml

The total time taken for settling of fly ash in the mixtures was found to be 2 hours 47 minutes at the reading 45ml of the mixtures in the flask.

Fly ash: 50 gm and water: 50 ml

Upper reading: 74 ml, lower reading: 72 ml

The total time taken for settling of fly ash in the mixtures was found to be 3 hours and 15 minutes at the reading 55ml of mixtures in the flask.

Fly ash: 35 gm and water: 65 ml

Upper reading: 82 ml, lower reading: 80ml

The total time taken for settling of fly ash in the mixtures was found to be 2 hours 40 minutes at the reading 39ml of the mixtures in the flask.

Fly ash: 25 gm and water: 75ml

Upper reading: 87 ml, lower reading: 84 ml

The total time taken for settling of the fly ash in the mixture was found to be 1 hours and 50 minutes at the reading 31ml of mixtures in the flask. From the above figure, the composition of fly ash: 25 gm and water: 75ml was found to be the better parameter among the other parameters for the separation of solid-liquid in slurries during the filling activity.

4.1.8 SLUMP TEST

The slump-height of the fly ash collected from Jindal Steel Plant was found to be 80mm.

4.2 CONCLUSION

- From the compositions of fly ash sample collected, it can be concluded that the fly ash sample belongs to ASTM class F.
- Visual observations of the SEM images show a distinct spherical nature for the grains for the fly ash samples.
- The specific gravity attribute to the mineralogical composition i.e presence of silica content and CaO.
- The moisture content of the samples were found out to be around 0.175% indicating that all the moisture have been evacuated and they are suitable for the construction works etc.

- Due to the fine grained nature of the solid constituents, the fly ash slurries exhibit marked sluggishness for settling and also did not provided clear supernatant solutions.

- The composition of fly ash: 25 gm and water: 75ml is the good parameter for the separation of solid-liquid in slurries during the filling activity.

- Pozzolanic properties of fly ash can be identified by presence/absence of calcium oxide. So class F fly ash is the weak in pozzolanic as very less amount of calcium oxide present.

- The chemical, physical and mineralogical properties of fly ash had appreciable effects on performance of fly ash in filling low lying and mine void areas.

- Bituminous (pozzolanic) fly ash is more frequently used to construct embankments and structural backfills than sub bituminous or lignite (self-cementing) fly ash. This is due in part to the self-cementing characteristics of the latter type, which hardens almost immediately after the addition of water.

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